Ecology of Indian Desert; IV– Photoperiods in relation to growth behaviour of two desert species of *Sida*[1]

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Varying photoperiods appeared to influence the growth patterns of two desert species of *Sida*. The photoperiod observed for the optimum growth in both the species was 12 hours. However, when compared among themselves, the fresh weight, dry matter accumulation and moisture content in *S. spinosa* were found to be always more than in *S. grewioides*. Flowering was first initiated in 9 and 12 hours photoperiodic exposures in *S. grewioides* and *S. spinosa*, respectively. *Sida grewioides* indicated a preference for longer photoperiod as the seedlings did not survive in less than 9 hours exposures, although in longer ones beyond 12 hours the plants remained only in vegetative state. In *S. spinosa* plants did not die even in 3 hours photoperiodic exposures in the 24 hours cycle, but remained in vegetative state like those in longer photoperiods of 18 and 24 hours.

INTRODUCTION

In the recent past voluminous information has been accumulated on the relation between growth behaviour and photoperiods in a number of plant species. The photosynthetic process in green plants which takes place in light masks the respiratory activity, since in the latter process, the products are broken down, which are produced in the former. The different photoperiods definitely affect the production and growth of new leaves resulting either in a well developed shoot system or a poor one, this in turn affects the productivity. The translocation of extra photosynthetic products to the root affects the growth and morphology of root system. Garner & Allard (1920) stress the importance of the length of the daily light periods as a factor influencing the growth and development of plants. Root growth and its subsequent development has always been recognised as important phenomenon.

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Light energy is one of the important factors affecting a large number of known and unknown biochemico-physiological processes as well as plant size and shape. In many plants the length of the daily photoperiods also regulate the meristematic activities (Kadam-Zahavi & Alvarez-Vega 1968). Flowering is primarily an ecological phenomenon, yet comparatively very little study of the flowering process has been made from purely ecological standpoint (Salisbury 1963). The photoperiods and temperature may act at any of the several stages in the ecological life cycle of any plant species. Several reviews on the physiology of flowering are available. Lang (1952) initiated the series covering photoperiodism and vernalization; whereas Liverman (1955), Doorenbos & Wellensiek (1959) and Salisbury (1961) emphasised the importance of mainly photoperiodism and plant growth.

Photosynthetic process is of paramount importance with respect to physiological adaptation of the species to the environment. Ketellaper (1965) has shown that dry matter production of tomato and soybean plant responds to variations in the length of the light-dark cycle. It has been earlier proposed that unfavourable cycles are injurious to plant growth (Ketellaper 1960; Tukey & Ketellaper 1963).

Light as the energy source is of primary importance which brings about the most striking changes as compared to other environmental factors. Information on the effects of photoperiods on the root and shoot growth, dry matter production, floral initiation and fruit setting in arid zone plants is extremely meagre. Floral initiation in long day plant and short day plant is determined by a floral stimulus, which is generated in the leaves under the influence of photoproduction and is then translocated to the growing points (Lang 1952). It is generally assumed that scarcity of water leads to the poor development of root and shoot system, but it also leads to early flowering and ultimately fruit setting which is based solely on field observations. To test this assumption, experiments were conducted on varying photoperiods in relation to two desert species of *Sida*.

Experimental methods

Five days old seedlings of *S. grewioides* and *S. spinosa* were transplanted in 12 cm wide earthen pots. One seedling per pot was maintained till the experiments were over. The soil in the pots was kept moist by regular watering and they were placed in shade in the beginning to ensure better seedling growth and establishment. After 10 days these experimental pots were exposed to various photoperiods viz., 3, 6, 9, 12 and 18 in the 24 hour cycle and also in continuous light. The extra light duration besides sunlight was supplied by six flourescent tubelights of

40 watts each from a distance of one meter. One set of plants was kept in total darkness. These experiments were started from 8th August 1969 and the observations were made up to 60 days (8th October 1969). During this period the durations of day and night periods were approximately equal. Three replicates of each set were used for the present study. The observations have been made for growth behaviour of root and shoot, fresh weights, dry matter accumulations, moisture contents, flowering and fruit settings. The temperature during the day remained 32° ± 2°C and in the night 24° ± 2°C.

Observations

(a) *Root and shoot growth*

The growth of the two *Sida* species in the experimental pots remained comparatively poor from those growing in nature, which may be due to edaphic factors. The growth analysis in different photoperiods has been given in tables 1 and 2.

Table 1

Growth performance of *S. grewioides* in different photoperiods after 30 and 60 days of treatment. All measurements are in mm.

Photoperiods in 24 hr cycle	Days	Main shoot length	Main root length	Length of longest lateral root	No. of axillary branches	Total No. of leaves per plant
3 hours	30	80	100	60	—	14
	60	—	—	—	—	—
6 hours	30	120	150	130	—	25
	60	—	—	—	—	—
9 hours	30	220	200	200	5	52
	60	253	310	330	9	98
12 hours	30	220	220	220	8	65
	60	320	480	360	11	113
18 hours	30	180	220	120	—	33
	60	240	310	220	—	54
24 hours	30	140	200	120	—	24
	60	180	240	180	—	44

It would be evident from table 1 that the root system was poorly developed in 3 hours photoperiodic exposures in both the plant species. The number and length of laterals were less when compared with plants in other photoperiodic exposures. *S. grewioides* could not survive in 3 and 6 hours photoperiodic exposures till the end of the experimental period. The growth of the root system was increasingly favoured with the increase in photoperiodic exposures up to its optimum period of 12 hours in both the species studied. However, the photoperiod beyond 12 hours exposure appeared to inhibit the growth of the root system. The best growth of root system in both the species was found in 12 hours photoperiods (Tables 1 and 2). Further increase in the photoperiodic exposures did not favour the growth of root system. When compared among themselves, the root system of *S. spinosa* was more extensive and better as compared to that of *S. grewioides.*

Similar to the root system, the shoot system was also poorly developed in 3 hours photoperiod (Tables 1 and 2). The shoot growth was progressively better with the increasing photoperiodic exposures. The best shoot growth in *S. grewioides* as well as in *S. spinosa* was observed in 12 hours photoperiodic exposures, which was similar to root system. In 12 hours optimum photoperiods these plant species exhibited maximum shoot branches and leaves.

TABLE 2

GROWTH PERFORMANCE OF *S. spinosa* IN DIFFERENT PHOTOPERIODS AFTER 30 AND 60 DAYS OF TREATMENT. ALL MEASUREMENTS ARE IN MM.

Photoperiods in 24 hr cycle	Days	Main shoot length	Main root length	Length of longest lateral root	No. of axillary branches	Total No. of leaves per plant
3 hours	30	180	180	81	—	10
	60	250	200	100	—	22
6 hours	30	370	320	260	18	94
	60	460	380	300	24	205
9 hours	30	400	400	300	20	110
	60	520	460	340	28	254
12 hours	30	550	450	400	26	163
	60	700	550	480	32	318
18 hours	30	380	330	290	8	72
	60	510	480	450	20	147
24 hours	30	290	230	275	4	57
	60	350	410	380	9	88

With respect to longitudinal growth, the data indicated that the length of photoperiods has a qualitative influence on both the species. Under relatively short photoperiods the plants remained stunted *S. grewioides* could not survive for 60 days under short photoperiods of 3 and 6 hours. Under longer photoperiods elongation of the main axis as well as lateral branches occured. Photoperiods longer than the optimum were found to be inhibiting shoot growth. However, *S. spinosa* expressed better growth performance when compared with *S. grewioides.*

TABLE 3

EFFECT OF DIFFERENT PHOTOPERIODS ON FRESH WEIGHT, DRY MATTER ACCUMULATION AND MOISTURE CONTENT IN ROOT AND SHOOT OF *S. grewioides* AFTER 30 AND 60 DAYS OF TREATMENT. ALL VALUES ARE IN GRAMMES

Photoperiods in 24 hr cycle	Days	Root			Shoot		
		Fresh wt.	Dry matter	Moisture content	Fresh wt.	Dry matter	Moisture content
3 hours	30	0.050	0.035	0.015	0.350	0.050	0.300
	60	—	—	—	—	—	—
6 hours	30	0.120	0.050	0.070	1.020	0.180	0.840
	60	—	—	—	—	—	—
9 hours	30	0.640	0.250	0.390	3.620	0.900	2.720
	60	3.300	0.870	2.430	10.400	2.920	7.480
12 hours	30	0.890	0.330	0.560	3.970	0.920	3.050
	60	3.500	0.940	2.560	10.800	3.070	7.730
18 hours	30	0.240	0.108	0.132	1.800	0.350	1.450
	60	0.840	0.190	0.650	2.500	0.490	2.010
24 hours	30	0.230	0.105	0.125	1.400	0.260	1.140
	60	0.520	0.150	0.370	2.000	0.320	1.680

TABLE 4

EFFECT OF DIFFERENT PHOTOPERIODS ON FRESH WEIGHT, DRY MATTER ACCUMULATION AND MOISTURE CONTENT IN ROOT AND SHOOT OF *S. spinosa* AFTER 30 AND 60 DAYS OF TREATMENT. ALL VALUES ARE IN GRAMMES

Photoperiods in 24 hr cycle	Days	Root			Shoot		
		Fresh wt.	Dry matter	Moisture content	Fresh wt.	Dry matter	Moisture content
3 hours	30	0.070	0.050	0.020	0.740	0.120	0.620
	60	0.170	0.080	0.090	1.500	0.740	0.760
6 hours	30	0.440	0.210	0.230	4.110	0.950	3.160
	60	2.250	0.520	1.730	6.900	2.520	4.380
9 hours	30	1.140	0.510	0.630	5.940	1.620	4.320
	60	2.500	0.730	1.770	8.600	3.370	5.230
12 hours	30	1.920	1.020	0.900	11.250	3.250	8.000
	60	8.790	2.290	6.500	13.800	6.950	6.850
18 hours	30	1.400	0.410	0.990	5.620	1.870	3.750
	60	4.290	1.450	2.840	12.100	6.500	5.600
24 hours	30	0.500	0.230	0.270	4.090	1.020	3.070
	60	1.590	0.390	1.200	6.300	1.920	4.380

(b) *Fresh weight, dry matter accumulation and moisture content*

The experimental plants died after a few days when placed in continuous darkness. The experimental plants of *S. grewioides* under 3 and 6 hours photoperiodic exposures could not survive up to the end of 60 days. The effect of different photoperiods on fresh weights, dry matter accumulations and moisture contents of root and shoot in *S. grewioides* and *S. spinosa* are given in tables 3 and 4.

It would be evident from table 3 that the maximum fresh weight in roots, 0.890 g and 3.500 g in *S. grewioides;* and 1.900 g and 8.790 g in *S. spinosa* in 30 and 60 days respectively, were found in both the species when exposed to 12 hours photoperiods. The maximum fresh weights of shoots in *S. grewioides* were 3.970 g and 10.800 g at the end of 30 and 60 days, respectively. The maximum fresh weights in *S. spinosa* were 11.250 g and 13.800 g at the end of 30 and 60 days, respectively. The fresh weight, dry matter and moisture contents of roots as well as shoots in both the species increased with the increasing photoperiodic exposures till 12 hours of the optimum. Further increase in photoperiodic exposures caused a decline in the fresh weights, dry matter accumulations and moisture contents.

(c) *Flowering and fruiting*

(i) *S. grewioides* — The effect of various photoperiods on flowering and fruiting status of this species at different intervals of time has been studied and expressed in table 5.

TABLE 5

THE FLOWERING AND FRUITING STATUS OF *S. grewioides* AT THE END OF 15, 30, 45 AND 60 DAYS AFTER THE PLANTS WERE EXPOSED TO DIFFERENT PHOTOPERIODS IN A 24 HOURS CYCLE.

No. of	Photoperiods in 24 hours Cycle					
days	3	6	9	12	18	24
15	—	—	fl	—	—	—
30	—	—	fr	fp	—	—
45	+	+	fr	fl	—	—
60	+	+	fr	fr	—	—

— = vegetative; + = plant did not survive; fp = floral primordia; fl = flowering; fr = fruiting.

It would be evident from table 5 that floral initiation in *S. grewioides* is controlled by 9 and 12 hours photoperiods. The first initiation of flowering could be observed as early as after 10 days in 9 hours and after 25-30 days in 12 hours photoperiodic exposures. The plants in other photoperiods remained vegetative.

Plants kept in total darkness did not survive and died within the period of 10 days of starting the experiment. The plants in 3 and 6 hours photoperiods died after 30 and 45 days, respectively. However, the plants under 18 and 24 hours photoperiods remained completely in vegetative state. The earliest fruit setting could be observed only in 12 hours photoperiods during the experimental period.

(ii) *S. spinosa* — The bud initiation to certain extent appeared to be apparently independent of photoperiods, but the formation of complete floral buds and flush of flowering in this species depended on the light exposures of definite periods. The flowering and fruiting status of the plants was estimated when the plants had already received the described photoperiods at the end of 15, 30, 45 and 60 days. The periodic observations for the above mentioned plant species have been tabulated in table 6.

TABLE 6

THE FLOWERING AND FRUITING STATUS OF *S. spinosa* AT THE END OF 15, 30, 45 AND 60 DAYS AFTER THE PLANTS WERE EXPOSED TO DIFFERENT PHOTOPERIODS IN A 24 HOURS CYCLE.

No. of	Photoperiods in a 24 hours cycle					
days	3	6	9	12	18	24
15	—	—	—	fp	—	—
30	—	fp	fl	fr	—	—
45	—	fl	fr	fr	—	—
60	—	fr	fr	fr	—	—

— = vegetative; fp = floral primordia; fl = flowering; fr = fruiting.

It is evident from table 6 that the first floral initiation was observed in 12 hours photoperiods as early as after 7 days of the start of the experiment. After 15 days additional floral initiation were observed in plants exposed to 9 hours photoperiods. Further initiation of flowering was seen later in plants exposed to 6 hours photoperiods. The plants kept in total darkness did not survive and died within 15 days of the start of the experiment. However, no floral initiation could be visualised in plants exposed to 3, 18 hours photoperiods and continuous light. Besides flowering, the first fruit setting was also observed in plants exposed to 6, 9 and 12 hours photoperiods during the experimental period.

DISCUSSION

Information on the effects of photoperiods on the plants of desert environment is extremely meagre. Hardly any plant species of arid region of India has been classified as to its photoperiodic requirements. *Sida grewioides* and *S. spinosa* appear to be influenced by day lengths. The photoperiods definitely affected the production and growth of new leaves and the magnitude of growth of roots and shoots. The leaves of the plants are perceptors of the radiant energy. The photoperiodic treatment of the leaves causes the photosynthetic apparatus to stimulate there. This photosynthetic apparatus starts different physiological and biochemical processes in the chlorophyllous organs of the plant.

Ketellaper (1965) showed that variations in the length of light-dark cycle affect the growth behaviour and dry matter production of tomato and soybean. Sharma & Sen (1971) observed that the growth behaviour and dry matter production in *Solanum nigrum* was changed with the different photofractions. Austin (1948) reported that in *Impatiens balsamina* fresh and dry weights of the aerial and subterranean parts were maximum under the 16 hours photoperiods. Root development was proportionally greater under longer photoperiods. The percentage of moisture contents in aerial system was greater under the longer photoperiods. Chawan (1970) has observed that various photoperiods definitely affected the growth behaviour of roots in *Corchorus aestuans* and the short photoperiods were unfavourable for the growth. It has been earlier proposed that unfavourable photofractions are injurious to plant growth (Ketellaper 1960; Tukey & Ketellaper 1963).

Wareing (1956) showed that there is a relation between the length of the optimal light period and the duration of dark period. The initiation of flower buds and their further development has been connected with the auxin production. Chawan & Sen (1971) showed that day length influence the bud initiation, the flush of flowering and specially the fruit setting in *Corchorus aestuans.* The morphological changes in the vegetative parts of shoot and the development of yellow-red pigments appeared to be connected with fruit setting in *C. aestuans*. Halaban (1968) stated that flowering response of *Coleus frederici* and *C. blumei* is dependent on the photoperiods. Both these plant species have a critical day length of about 12 hours. Photoperiodic effects on floral initiation in a wide variety of plants have been thoroughly reviewed in recent years (Chouard 1960; Lockhart 1961; Salisbury 1963).

The growth behaviour, flowering and fruit setting in the two species of *Sida* have been studied from purely ecological standpoint in this study. Short photoperiodic exposures were found to be unfavourable for the plants. Certain photoperiodic exposures were the direct requirements for flower initiation and fruit setting. This may be interpreted as (a) complete absence of floral initiation in plants exposed to certain photoperiods, (b) change in the growth behaviour of root and shoot system, (c) plants not getting sufficient daily photoperiodic exposures remained vegetative for a long time, when in contrast to those getting the required photoperiods flowered and showed fruit setting in the experimental duration of 60 days.

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References

Austin, J. P. (1948): The influence of length of photoperiod on the vegetative and reproductive development of *Rudbeckia bicolor superba, Delphinium ajacis, Cosmos sulpheurs* and *Impatiens balsamina. Amer. J. Bot 28*: 244-250.

Chawan, D. D. (1970): Ecophysiological observations on arid zone plants with special reference to seed germination and rhizology. Ph.D thesis, Jodhpur University (unpubl.).

——————— & Sen, D. N. (1971): Photoperiodic influence and floral initiation and fruit setting in *Corchorus aestuans* Linn. (in press).

Chouard, P. (1960): Vernalization and its relation to dormancy. *Ann. Rev. Pl. Physiol. 11*:191-238.

Doorenbos, J. & Wellensiek, S. J. (1959): Photoperiodic control of floral initiation. *Ann. Rev. Pl. Physiol. 10*: 147-184.

Garner, W. W. & Allard, H. A. (1920): Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants. *J. Agri. Res. 18*:553-606.

Halaban, R. (1968): The flowering response of *Coleus* in relation to photoperiod and the circadian rhythm of leaf movement. *Pl. Physiol., 43*:1894-1898.

Kadam-Zahavi, A. & Alvarez-Vega (1968): The use of coloured light for agriculture. Final report to Ford Foundation Grant No. A-6/5.

Ketellaper, H. J. (1960): Interaction of endogenous and environmental periods in plant growth. *Pl. Physiol. 35*:338-341.

——————— (1965): Interaction of endogenous and environmental periods in plant growth. *Pl. Physiol. 38*:337-345.

Lang, A. (1952): The physiology of flowering. *Ann. Rev. Pl. Physiol. 3*:265-306.

Liverman, J. L. (1955): The physiology of flowering. *Ann. Rev. Pl. Physiol. 6*:177-210.

Lockhart, J. A. (1961): Mechanism of photoperiodic process in higher plants. Encyclopaedia Plant Physiol. *16*:390-438 (ed. W. Ruhland, Springer-Verlag, Berlin).

Salisbury, F. B. (1961): Photoperiodism and flowering process. *Ann. Rev. Pl. Physiol. 12*:293-326.

——————— (1963): The flowering process. Pergamon Press, New York.

Sharma, K. D. & Sen D. N. (1971). Photofraction in relation to growth behaviour in *Solanum nigrum* Linn. *Oecol. Plant. 6*:35-42.

Tukey, H. B. Jr. & Ketellaper, H. J. (1963): Length of the light and dark cycle and plant growth. *Amer. J. Bot. 50*:110-115.

Wareing, P. F. (1956): Photoperiodism in woody plants. *Ann. Rev. Pl. Physiol. 7*:191-214.